Simulation and Optimization for Modeling the Passengers Check-in System at Airport Terminal

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ABSTRACT

Delays in the passenger check-in system will create delays in flights departure that will lead to gates assignment conflicts especially during peak times in some airports. Therefore, improving the efficiency of check-in counters at airport passenger terminals is a major concern of airport operators and airlines. By using simulation, the check-in system can be modeled and the effects of various parameters – such as number of passengers on a flight and number of counters – can be studied. In this research, various scenarios were evaluated for the check-in procedure for Kuwait airways at Kuwait international airport. The objective is to minimize the operational cost from incurred by the airline duty counter personnel and maximize passenger service level.

Keywords: Airport, Check-in counter, optimization, simulation.

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1. INTRODUCTION

The development of air transport activity worldwide has increased the demand for airport services and the need for more efficient processes of servicing aircraft, passengers or luggage. The arrivals of passengers at airport check-in counters represent a random process with variable arrival rates over time depending on type of flight. Since the passenger arrival generally tend to occur at higher rates close to the beginning or in the middle of the scheduled check-in, it is worth determining when additional counter(s) should be opened or closed. This problem becomes more complicated for large airlines at busy airports where they manage the check-in process for multiple flights. A simulation model were developed here for optimizing the number of check-in counters as well as their opening and closing times in order to estimate the operational cost by the airline duty counter personnel and passenger waiting time in the queue for both economy and business or first class. Several of papers has considered simulation and optimization of air traffic, P. Zoppoli (2008) and passenger flow C. A. Chung (2000), P. E. Joustra (2001), H. Che (2007), G. Guizzi (2009), T. Oyama (2003), E. Valentin (2002) have been already proposed. Based on simulation results, approaches for improving airport passenger flow by design and optimization have been presented in R. Moriyama (2002), A. R. Odoni (2004), Chin-Wu Lin (2009). The importance of quality of service for customers has also been recognized by many researchers including Janic (2000), Martel and Seneviratne (1990) and Helmiatin (2016). The customers in this context are passengers and airlines; however, this study is focused on passenger activity only. The scope of this research work is to provide a convenient methodology to make

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approximate estimations for passenger processing areas. Passengers are typically the main source of revenue for airports (Martel and Seneviratne, 1990). Therefore, the design of service facility needs to consider passenger requirements. Formulations of the space required at airport check-in areas are also considered by a number of researchers. Work presented by Ashford (1988), IATA (1989), Horonjeff (1994), Seneviratne and Martel (1995) and Subprasom et al. (2002) are particularly relevant in this context. Martel and Seneviratne (1990) have investigated the relative importance of performance measures using a field survey. International Air Transport Association (IATA, 1989) provides formulae for estimation of the number of check-in counters and recommended space for passengers in queues. These formulas are based on peak hour passenger flows. However, passenger arrival distributions, queue arrangement and check-in counter capacity are also important elements in designing check-in area facilities.

This paper presents various scenarios for the check-in planning problem based on queueing and simulation tools at the level for which the flight demands are known. That is, with the flights and check-in times for these flights known at a daily level and the number of actual travelers and the traveler arrival times and the check-in times were estimated. The simulation model will be applied for Kuwait airways (ICAO Code: KAC) passenger flights at Kuwait international airport (KIA). KIA air transportation has grown at a rapid pace in the last ten years after applying the "open sky" policy from 2006. As a result, the average passenger annual growth rate is about 10% and forecast figures shows more growth rates in the next coming years. KAC is the largest operator at KIA. The company is willing to add more destinations, increase number of flights and number of fleet in few years. Our focus in this research is to evaluate the check-in procedure for KAC at KIA and then minimizing the operational cost from incurred by the airline duty counter personnel while maximizing passenger service level.

2. PROBLEM DESCRIPTION AND DATA COLLECTION

KIA is divided into four check-in zones areas. Each zone area has different total number of check-in counter capacity. KAC flights are located in a zone that has the highest number of counters. Furthermore, the total number of check-in counters that assigned for KAC flights is currently 25 counters. Their designated ground-handling agents manage KAC passenger flights check-in procedures. Currently, the number of check-in counters for each flight is performed manually based on prior experience and simple heuristics. This procedure relies on the resource requirements provided by KAC and the experience and skill of the human schedulers. However, the upcoming season tend to request more check-in counters than the counters total capacity. The process of checking in passengers is stochastic, and the number of required check-in counters varies with factors such as number of passengers, type of aircraft and destination. Due to this complexity, it is hard for a human to predict without a simulation tool that measures the resource requirements accurately on a daily basis. This problem required an accurate estimation of the actual check-in counter requirement for each departing flight.

We have collected all flights departure schedule for KAC during the summer season for one-week period when the flights and passengers movements reach their peak. The data contains the flights details such as flight number, type of aircraft,

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departure time and day. Then we forecast the number of departure passengers per flight depending on historical passenger movement statistics and total seat capacity of an aircraft and destination. The check-in process is usually takes about two hours period. The check-in process starts three hours before flights departure and closes before one hour before departure.

The required number of check-in counters should satisfy two basic goals. The first basic goal is that there should be enough counters to process all the passengers boarding the flight before counter closing time. The other goal is related to service quality. Depending on the historical data and the requested number of counters for each flight, we have concluded in our previous paper (Al-Sultan, A.T. (2016)) that on the average the number of passengers that can be served for one counter during check-in period is about 40 passengers for all airlines. For example, if the estimated number of departure passengers for a specific flight is 200 passengers, then the required number of check-in counters for this flight is 5 counters which including all seats class (economy and business or first class). However, our research is focusing on one airline. If multiple flights are scheduled to operate in the same period, then we take the sum for the expected number of departure passengers for those flights and divide by 40 and assign 90% of counters to the economy class and the rest for the business and first class.

The concept of Level of Service (LOS) is an aggregated guidance framework for the planning of new terminal facilities as well as for monitoring the operational service performance of existing facilities. In this paper, we will focus on two important variables jointly dictate the LOS the passenger average waiting time in the queue and space (m^2) at check-in area. The acceptable processing and waiting times for the first or business class travelers is expected to be less than the processing and waiting times for economy class travelers. In KIA, we assumed that the percentage of passengers using carts (row width 1.4m) is high. The total space available in the check-in area is about $1507.25\,m^2$. In addition, the maximum capacity for the number of passengers in KAC check-in area is also calculated to be $107.14 \approx 107$ passengers based on the assumption that the percentage of passengers using carts is high. Table I shows the suggested LOS standards by (IATA, 1989). We will compare these LOS standards with the simulated scenarios in section III.

Table I
Suggested LOS Standards for average waiting time (min) and Average Space (sq. Meter)

LOS	Average Waiting Time (min)	Average Space (m^2)
A (excellent comfort)	< 1	2.3
B (high comfort)	1 - 17	1.9
C (good comfort)	17 - 34	1.7
D (adequate comfort)	34 - 58	1.6
E (inadequate comfort)	> 58	1.5

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In KIA, the staffing cost in the check-in counter is $60 per hour. From the collected one-week data, we have 319 departure flights for 38 destinations for KAC. We have calculated the required number of counters for whole week. Fig.1 describes the current situation for required number of counters after we forecasted the number of departure passengers for each flight and divide by 40. We can notice from the graphs that the required number of counters exceeds the capacity around 6:00AM to 8:00AM and around 2:30PM to 4:30PM.

During peak hours, queuing can be a major problem for both passengers and ticket agents. Although it seems to be a very straightforward process, the fluctuations in demand throughout the day can cause delays that will lead to other delays in the scheduled departure time. The time the customer spends waiting is directly related to their satisfaction. Therefore, the overall objectives of this research are:

1. Use this information to develop a simulation (using Arena software) that shows the passenger flow through the check-in process given the different types of check-in scenarios.
2. Analyze different scenarios on the basis of the followings:
   - Passengers average number and waiting time (in the queue) in both economy and first or business class.
   - Average space per passenger.
   - Calculate the total staffing cost per week.

In order to minimize the operational cost from incurred by duty counter personnel and maximize passenger service level.

3. Finally give some recommendations for KAC passenger check-in procedures.

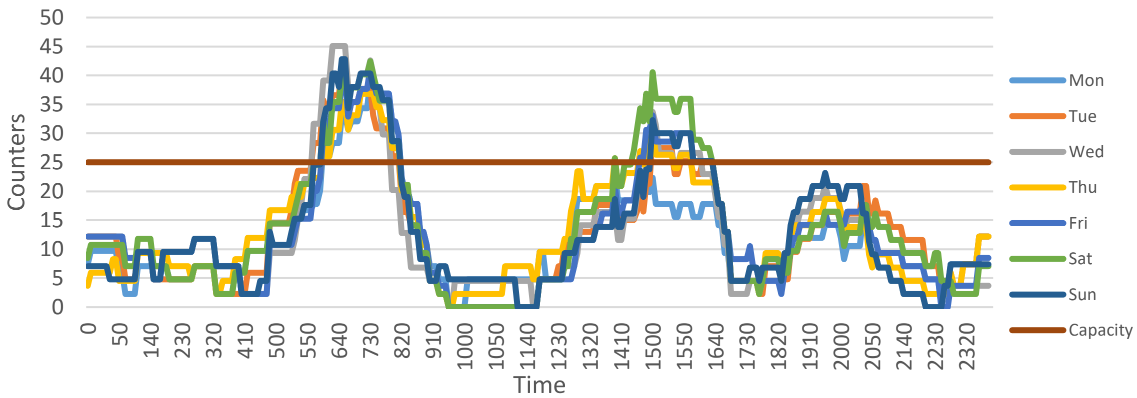

Figure 1: The current situation for the required number of counters for KAC.

3. SIMULATION MODEL

The check-in system encounters variabilities on the capacity and check-in planning prior to the actual operations. These variabilities are to be regarded as subject to uncertainty (stochastics). In this paper, we will consider the check-in planning problem at the level for which the flight demands are known. That is, the number of actual travelers for each flight was estimated (see Section II). Nevertheless, a number of aspects remain uncertain as the traveler arrival times and the check-in times. Simulation is used to evaluate and improve operational and personnel planning in order meet a

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service level for each separate flight. We used ARENA to apply the simulation model. We have collected the necessary data to look for the appropriate data distribution for passengers inter-arrival times. Expertfit and Input Analyzer were used to come up with the appropriate data distributions. Inter-arrival times mostly fit to Gamma (3, 15), and the distribution of one counter service time is assumed to be Uniform (2, 3) minutes.

Passengers are treated as individual entities and we have put in our consideration the opening and closing time for each counter for each flight, the expected number of passengers and the required number of counters for each flight. For each flight, we assumed that first and business class passengers represent 10% of the total number of passengers. Fig.2 presents an example for the amount of passenger arrival time three hours before the departure time of a flight. The figure illustrates 100 passengers arrival pattern before flight departure time after fitting the Gamma distribution. The standard planning would allocate a fixed number of 3 counters during the 2 hours check-in period. Furthermore, Fig.2 is very close to the real situation in (KIA) since all of the flights are international flights and most of the passengers tend to arrive early especially the passengers with a long-haul flight to avoid missing the flight or waiting in a long queue. By simulation (as well as measurements), this led to mean waiting times of approximately 20 minutes. More seriously though, during the first opening hour, during which over 60% of all passengers have arrived, excessive waiting times in the order of 40 minutes were measured, while 10 minutes in the second hour.

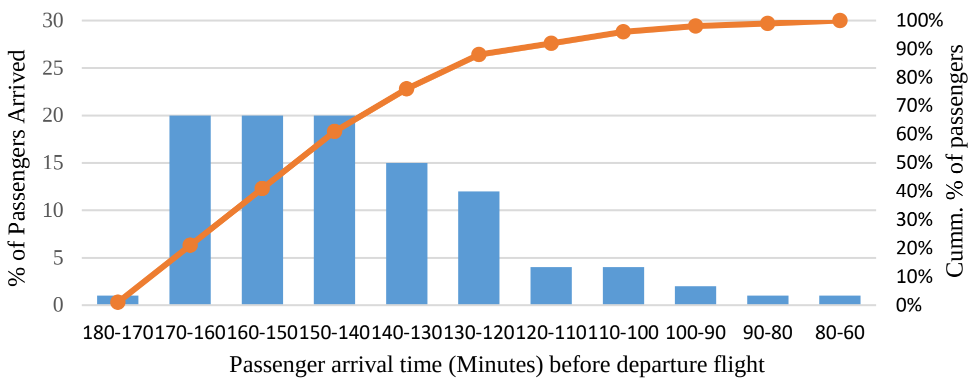

Figure 2: Passengers arrival pattern

For minimizing the counter personnel cost and maximize passenger service level, we will simulate and compare the current situation for passengers check-in system for KAC with 15 check-in scenarios. The number of check-in counters for KAC is currently constant during the working hours. For example, if a flight needs 4 counters to process the passengers, the number of counters remains fix during the 2 hours check-in period. Furthermore, there are some negotiations between the airport officials to change airline to check-in allocation in order to give more counters to KAC. Our research shows that it is possible the number of counters could be increase from 25 counters to 27 counters. Two express kiosks could be installed as well. The passenger using the express kiosk should not checking with any bags will receive the boarding pass. From our investigations in other check-in zone, there were very few passengers are using kiosks.

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Therefore, we have assumed in our simulation model that the percentage of passengers using express kiosk is low (around 2%). The staffing cost for the express kiosk is calculated by the estimated utilization of service time when a passenger is using a kiosk. This is according to our assumption that the passenger will need an instructor staff to guild the passenger how to use the express kiosk. Table II presents descriptions for all scenarios investigated for KAC for their current and future operation.

Table II
Scenarios description summary

Scenario	Counters requirements	Queue system	Description
Current Situation	Constant	Single Queue	Check-in Counters=25, Number of Kiosk =0
Scenario 1	Constant	Single Queue	Check-in Counters=25, Number of Kiosk =2
Scenario 2	Constant	Single Queue	Check-in Counters=27, Number of Kiosk =0
Scenario 3	Constant	Single Queue	Check-in Counters=27, Number of Kiosk =2
Scenario 4	Constant	Multiple Queues	Check-in Counters=25, Number of Kiosk =0
Scenario 5	Constant	Multiple Queues	Check-in Counters=25, Number of Kiosk =2
Scenario 6	Constant	Multiple Queues	Check-in Counters=27, Number of Kiosk =0
Scenario 7	Constant	Multiple Queues	Check-in Counters=27, Number of Kiosk =2
Scenario 8	Variable	Single Queue	Check-in Counters=25, Number of Kiosk =0
Scenario 9	Variable	Single Queue	Check-in Counters=25, Number of Kiosk =2
Scenario 10	Variable	Single Queue	Check-in Counters=27, Number of Kiosk =0
Scenario 11	Variable	Single Queue	Check-in Counters=27, Number of Kiosk =2
Scenario 12	Variable	Multiple Queues	Check-in Counters=25, Number of Kiosk =0
Scenario 13	Variable	Multiple Queues	Check-in Counters=25, Number of Kiosk =2
Scenario 14	Variable	Multiple Queues	Check-in Counters=27, Number of Kiosk =0
Scenario 15	Variable	Multiple Queues	Check-in Counters=27, Number of Kiosk =2

Where:

- Counters requirements: The constant counter requirements has fix number of counters during the working hours. While in the variable counters requirements, we add one extra counter in the 1st hour and reduce two counters in the 2nd hour after opening the counter.
- Queue system: represents the type of queue system. In the single queue, all arrival passengers stand in one queue then proceed to the available counter. In in the multiple queues system, every check-in counter has a single queue.
- Description: shows different cases for the number of the regular check-in counters and number of express kiosk in case of installation.

The variable counters requirements was proposed in order accommodate the high percentage of passengers arrival in the first hour due to the nature of the estimated inter-arrival distribution (Gamma distribution). Table III represents the simulation results for LOS variables and the total staffing cost (per week). We will focus on the scenarios with single queue system (the Current Situation, scenario 1, 2, 3, 8, 9, 10 and 11) since the results shows that the single queue system is better than the multiple queue system concerning both passenger waiting time and number of passengers in the queues. Furthermore, this result was expected due to the variabilities in the service time in the check-in counter from one passenger to other passenger. The scenario for the current situation shows an adequate comfort (D) for LOS in Average of waiting time and space (m^2). However, the during peak hours, the waiting time reach over 90 minutes (inadequate comfort) which an indication to undesirable long queues. Furthermore, the

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maximum area space capacity is also expected to be exceeded during peak hours. The simulation result shows approximately 125 passengers will be waiting in the queue that is 17% over the capacity.

From the results, it is obvious that the scenarios with single queue systems and variable counter requirements (scenario 8, 9, 10 and 11) have better results regarding the LOS and staffing cost than the other group of scenarios. Since the current situation applying constant check-in counters requirements during working hours, double win was so obtained. Not only in minimizing check-in counters (staffing) cost but also in minimizing average waiting time.

Table III
Simulation Results for LOS variables and total weekly staffing Cost

Scenario	Passenger Waiting time (Minutes)				Passengers in the Queue				Average Space per Passenger (sq. Meter)	Total staffing Cost (Per Week)
	First & Business Class		Economy Class		First & Business Class		Economy Class			
	Average	*Maximum*	*Average*	*Maximum*	*Average*	*Maximum*	*Average*	*Maximum*		
Current Situation	6.319	14.715	43.544	93.937	0.275	20.500	43.648	125.250	1.62	$80,746
Scenario 1	0.632	3.211	40.385	82.204	0.040	4.500	42.976	112.250	1.64	$81,553
Scenario 2	4.739	11.037	32.658	70.453	0.206	15.375	32.736	93.938	1.72	$82,566
Scenario 3	4.297	10.006	29.610	63.877	0.187	13.940	29.680	85.170	1.74	$83,392
Scenario 4	14.470	28.886	72.087	144.102	0.597	35.000	92.292	176.000	1.22	$80,746
Scenario 5	13.457	26.864	67.041	134.015	0.556	32.550	85.831	163.680	1.21	$81,553
Scenario 6	10.852	21.664	54.065	108.077	0.448	26.250	69.219	132.000	1.51	$82,566
Scenario 7	9.840	19.642	49.019	97.989	0.406	23.800	62.758	119.680	1.62	$83,392
Scenario 8	0.943	3.942	24.578	56.595	0.065	5.000	31.548	78.250	1.77	$66,212
Scenario 9	0.877	3.666	22.858	52.633	0.060	4.650	29.340	72.773	1.78	$66,874
Scenario 10	0.707	2.957	18.434	42.446	0.049	3.750	23.661	58.688	1.85	$68,032
Scenario 11	0.641	2.681	16.713	38.485	0.044	3.400	21.453	53.210	1.99	$68,712
Scenario 12	2.168	9.067	56.530	130.169	0.150	11.500	72.560	179.975	1.59	$66,212
Scenario 13	2.016	8.432	52.573	121.057	0.139	10.695	67.481	167.377	1.61	$66,874
Scenario 14	1.626	6.800	42.398	97.626	0.112	8.625	54.420	134.981	1.58	$68,032
Scenario 15	1.474	6.165	38.441	88.515	0.102	7.820	49.341	122.383	1.67	$68,712

Table IV gives the saving percentage for LOS variables and total weekly staffing cost between the scenario for the current situation and the scenarios that have single queue system. The saving percentage was calculated by taking the difference between the current situation and the new scenario divided by current situation. If the saving percentage was positive, then the scenario gives better result than the current situation. For example, in scenario 3 if we a add two extra counters and two express kiosks, the passengers average waiting time in the queue is expected to be decreased by 32.0%, and the number of passengers by 32.0% and the space per passenger by 7.4%. However, the weekly staffing cost is expected to be increased by 3.3% (which is a negative result).

KAC should consider applying a variable counters requirements scenario. If the maximum budget for weekly check-in staffing cost should be around $70,000 per week, then scenario 11 is recommended to be applied since it has the best option among other scenarios regarding the LOS and staffing cost. The average waiting time gives B rank

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(high comfort) while during peak hours gives D rank (adequate comfort). If KAC is considering the minimum staffing cost, then scenario 8 is recommended to be applied. However, the average waiting time gives C rank (good comfort) and during peak hours gives also D rank (adequate comfort). In general, a low cost in system operation leads to longer waiting times, while a higher cost in system operation leads to shorter waiting times. However, there is a significate difference between constant and variable counters requirements regarding staffing cost and LOS variables. Fig.3 shows the effect of staffing cost on the passenger average waiting time in the queue for both constant and variable counters requirements.

Table IV
Saving percentage for LOS variables and staffing cost for single queue system

Scenario, (Counters requirements)	%Average saving percentage (from Current Situation)			%Staffing Cost saving
	Waiting time	Passengers in the Queue	Space per Passenger	
Scenario 1, (Constant)	7.3%	1.5%	1.2%	-1.0%
Scenario 2, (Constant)	25.0%	25.0%	6.2%	-2.3%
Scenario 3, (Constant)	32.0%	32.0%	7.4%	-3.3%
Scenario 8, (Variable)	43.6%	27.7%	9.3%	18.0%
Scenario 9 (Variable)	47.5%	32.8%	9.9%	17.2%
Scenario 10, (Variable)	57.7%	45.8%	14.2%	15.7%
Scenario 11, (Variable)	61.6%	50.9%	22.8%	14.9%

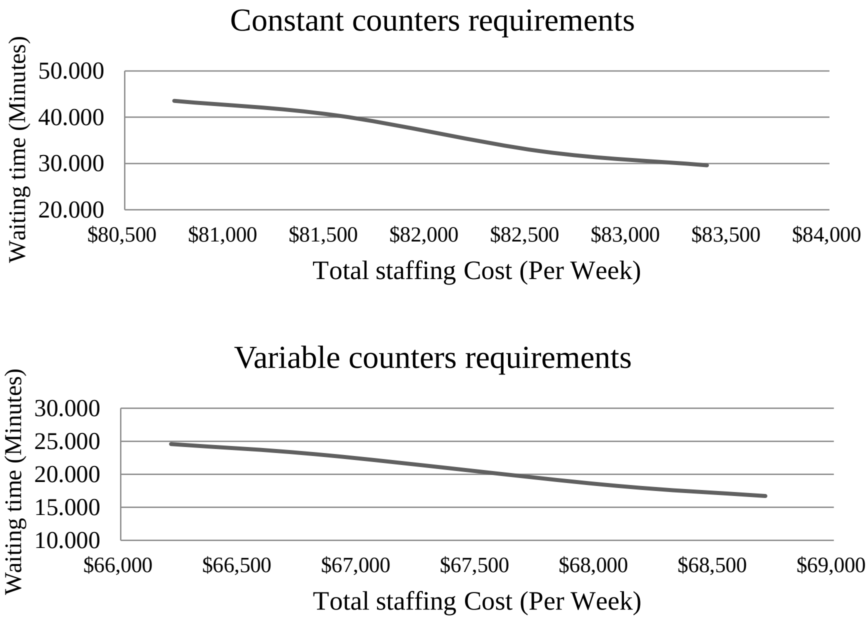

Figure 3: Average waiting time and Total staffing cost (per week).

4. CONCLUSION

In this paper, we have introduced several scenarios to accommodate the passenger during check-in system for airport terminal. Simulation modeling was used to study the queuing processes and to evaluate and improve operational and personnel planning in order to meet a level of service (LOS) and minimize the staffing cost. We have analyzed

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the check-in procedure for Kuwait airways (KAC) at Kuwait international airport (KIA). By studying the amount of passengers for each flight and their arrival patterns, we have analyzed various scenarios in order to support decision making processes in the passenger check-in system by studying the effects of various changes in variables, such as how many agents to keep when multiple flights are operating in the same time and what type of queuing system should be applied. Conclusions and decisions can be made regarding the behavior of the check-in system. This may prove to be a helpful tool in airport management systems or an airline to forecast, optimize and make important decisions in passenger level of service (LOS).

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